Some New Developments in

Active Noise Control

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Technology

Two Kinds of Cancellation:

Signal Separation:

Example: Army HMMWV Noise Canceller

Active Cancellation:

(Noise or Vibration)

Example: Cancel Interior Noise in Aircraft

Dr. Martinez's

Commonly Asked Questions (and our answers)

- What are we trying to accomplish? *Effective multichannel noise cancellation.*
- How is it done now, and with what limitations? SFR-SVD algorithm. Robust, effective but > computing.
- What is truly new in this approach which will remove current limitations and improve performance? By how much? Eliminates redundancies, ill-condition, permits accurate solution to filter equation, hence effective cancellation. Gain 15 20 dB vs. noise across band.
- If successful, what difference will it make?

 Has greatly improved noise cancelling performance.

Noise Cancellation: State of the Art

Excerpts from 1995 Navy SBIR Solicitation

- "Active control of noise and vibration has received a great deal of attention and achieved a certain level of practicality. However, active control methods have some limitations and drawbacks that additional research and development efforts are needed . . .
- "Most important, current control strategy needs to be extended to off-resonant, and broadband vibration and acoustic control."

Noise Cancellation: State of the Art

Excerpts from 1997 Air Force SBIR Solicitation

- "Active Noise Control has advanced significantly in recent years, but most applications to date have addressed physical systems with relatively limited spatial or temporal complexity.
- "For example, noise is reduced at a single headset location or only for small numbers of sources contributing narrowband or perhaps multi-tonal input."

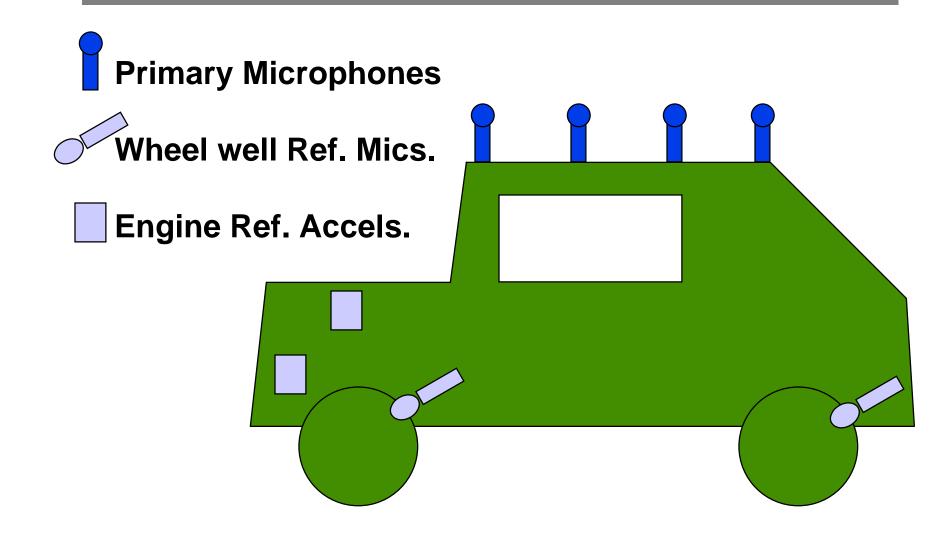
Noise Cancellation: State of the Art

Excerpts from 1993 Army SBIR Solicitation:

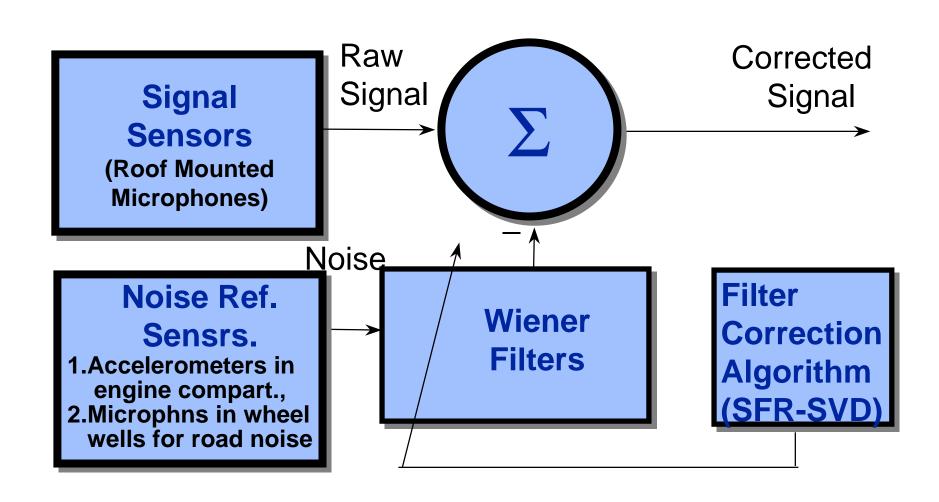
"Weapon platform and own-vehicle interference tend to degrade passive aero-acoustic sensor performance . . .

"ANC (Automatic Noise Cancellation) techniques such as the classic Widrow algorithm have been considered for cancellation of such interference, but . . . have not offered the degree of cancellation needed . . ."

HMMWV Instrumentation

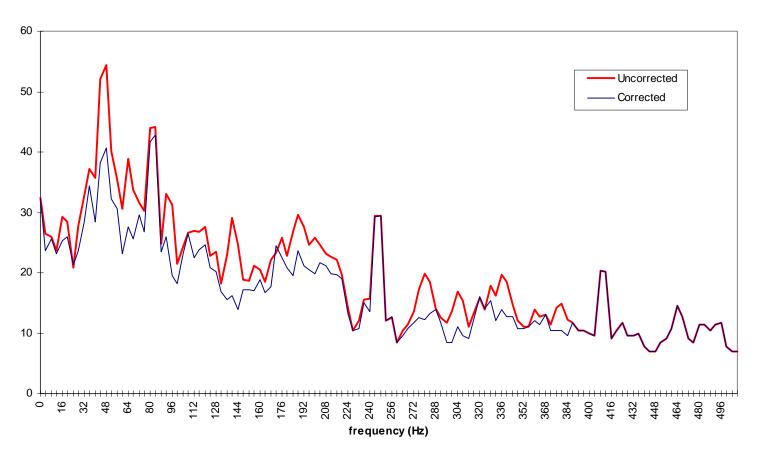


Signal Separation: How It Works



HMMWV Idling Using 5 Noise References

Power spectral density (dB)



Noise References:

Transmission fluid accelerometer Valve Cover accelerometer Tailpipe accelerometer Starter motor microphone Alternator microphone

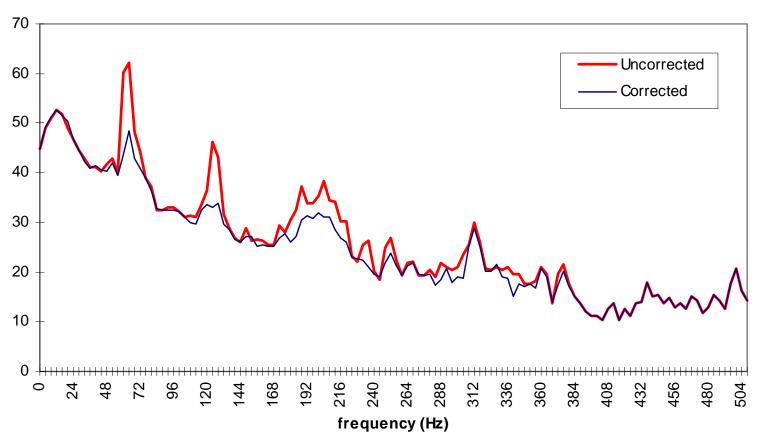
Signal:

82 Hz tone from loudspeaker 30 yards away

Signal Separation Technologies

HMMWV Moving at 10 mph, 5 Noise References

Power spectral density (dB)



Noise References:

Transmission fluid accelerometer Valve Cover accelerometer Tailpipe accelerometer Starter motor microphone Alternator microphone

No Signal

Signal Separation Technologies

SVD Calculations

Filter Equation:

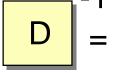
or

Diagonalize R with unitary U,

where D is diagonal.

$$= \begin{bmatrix} d_{big1} & \underline{0} \\ d_{big2} & \underline{0} \end{bmatrix}$$

Pseudoinverse:



0 inst. of reciprocal of d_{small}.

Calculate w using pseudoinverse of D:



This information is covered by U.S. Patents 5,209,237, 5,917,919, and foreign patents.

SFR-SVD Cancelling Algorithm

Ref. Sensor Measurements can be Redundant:

Occurs when noise references exceed no. of effective noise sources

Such redundancies must be eliminated:

Failure to do so degrades noise canceling performance.

SFR-SVD Method Eliminates Redundancies.

SFR-SVD has been thoroughly tested off-line:

- Army HMMWV Acoustic System: Engine, road noise reduced 20-30 dB;
- NASA aircraft Interior (active) Noise Reduction: 30 dB reduction;
- Navy towed array sonar: Accelerometers cancel vibration effects;
- Fetal electrocardiography: Maternal heatbeat removed.

Army HMMWV Project is First time realtime:

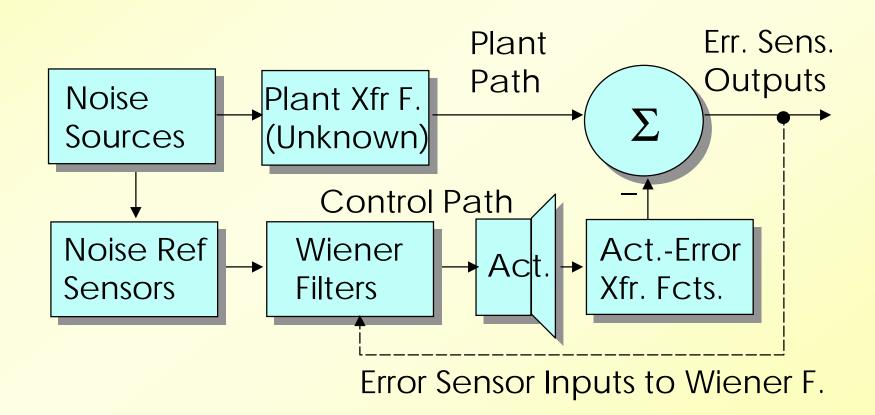
Developing world's most capable multi-channel cancellation computer.

This information is covered by U.S. Patents 5,209,237, 5,917,919, and foreign patents.

Summary

- The LMS and FXLMS (for active control) algorithms do not work well in a multi-channel control scenario, either for signal separation or for active control.
- The SFR-SVD algorithm has been shown to overcome the problems of redundancy and ill-condition.
- A real-time signal separation controller built for the Army has been found to be extremely effective.
- Use of SFR-SVD for active control was tested off-line for NASA; work on a real-time active vibration controller continues under an NSF SBIR grant.

Feed-Forward Active Cancellation: How It Works



SFR-SVD Computer is Proven Technology

1995: Phase I SBIR: Off-line Tests Using Real Data from Army HMMWV Demonstrate SFR-SVD Method's Ability to Enable HMMWV Air Acoustic Sensor System.

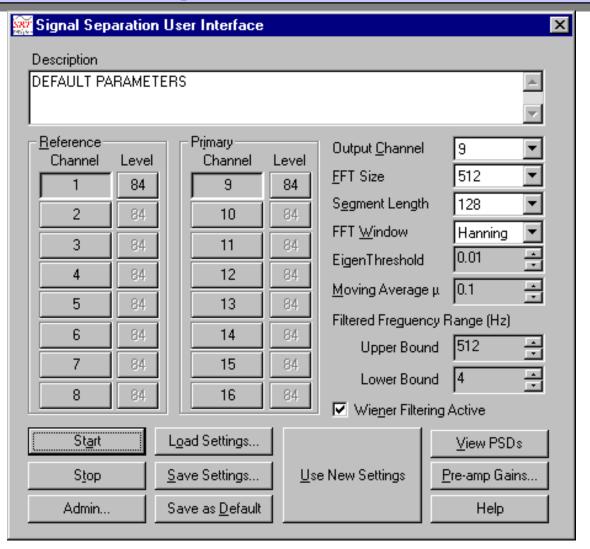
1996-97: Phase II SBIR: SST Builds Real-time Signal Separation Noise Canceller.

1997: Laboratory and HMMWV Field Tests Successful; Noise Canceller Performance Exceeds All Expectations; Final Report is Issued.

NSF Phase I SBIR: Application of SFR-SVD to Active Control of Vibrations.

1998: NSF Phase II SBIR: Active Control of Vibrations 1999: NSF Phase I SBIR: Noise Cancelling in Automotive environment.

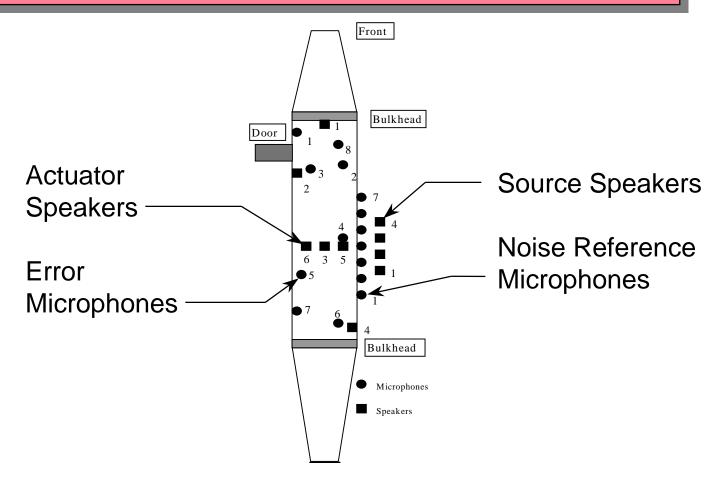
The Graphic User Interface



This information is covered by U.S. Patents 5,209,237, 5,917,919, and foreign patents.

Active Control of Noise/Vibration

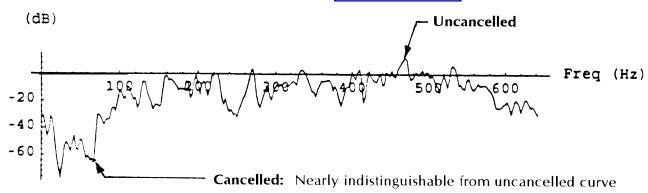
Active Noise Control in an Aircraft Fuselage Experimental Setup



Active Control of Noise/Vibration

Active Noise Control in an Aircraft Fuselage Comparison of Gains Achieved

→ Gain Against Noise When Using Classical LMS:



➡ Gain Against Noise When Using SFR-SVD Method:

